CLINICAL BRIEF

The Effects of Fluid Hydration Status on Ultrasound Muscle Measurement in Hemodialysis Patients

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Objective: This study aimed to explore the effects of fluid hydration status on ultrasound muscle measurement in hemodialysis (HD) patients.

Methods: Ultrasound muscle examination of the right rectus femoris and bioelectrical impedance analysis measurement of the right lower limb were performed in HD patients at the periods of predialysis and postdialysis. The correlations between the changes in the corresponding ultrasound and bioelectrical impedance analysis variables were analyzed.

Results: A total of 50 patients on maintenance HD were included, with mean age of 52.6 ± 13.5 years. Patients were 40% female (n = 20), and average dialysis duration was 2.62 ± 2.42 years. Compared to predialysis, the measurements of cross-sectional area, muscle thickness, echo intensity (EI), and their percentage changes all decreased significantly after the HD procedure ($P < .05$). The change in EI and its percentage change were significantly correlated with changes in total body water, intracellular water, and extracellular water ($P < .05$).

Conclusions: The HD session may have significant effects on ultrasound muscle measurement. Both the indicators of muscle quantity (cross-sectional area and muscle thickness) and quality (EI) significantly decreased after HD, which may contribute to the change in fluid hydration status and the change in fluid composition.

Keywords: Muscle quality; ultrasound; hemodialysis; fluid hydration

Introduction

PATIENTS ON HEMODIALYSIS (HD) often suffer from protein energy wasting, muscle wasting, and muscle weakness. Skeletal muscle mass and muscle function are negatively affected by a variety of conditions inherent to chronic kidney disease (CKD) and to dialysis treatment,[1] and many studies in the past decades have also linked muscle loss in CKD patients with worse quality of life, depression, protein-energy wasting (PEW), fracture risk, cardiovascular complications, graft failure, and postoperative complications in transplant recipients, as well as with increased hospitalization and mortality.[2] The evaluation of muscle mass and function may help formulate intervention measures and improve the prognosis for patients on HD.

Traditionally, skeleton muscle mass can be assessed by imaging methods such as dual X-ray absorptiometry (DXA), computed tomography, and magnetic resonance imaging, but these techniques are not commonly used in normal clinical practice due to radiation exposure, special operation room, and high cost.[3]

Instead, ultrasound offers essential advantages, including bedside operation, convenience, noninvasiveness, and lack of radiation use.[4] It has recently been widely adopted as a tool in assessing skeleton muscle in patients of different profiles, with right internal and external consistency.[5] The sizes of muscle thickness (MT) and cross-sectional area (CSA) measured are usually used to indicate muscle quantity, while muscle echo intensity (EI) is used as an important indicator of muscle quality.[6] The ultrasound parameters MT, CSA, and EI have all been applied in both dialysis-dependent and non–dialysis-dependent CKD patients.[7,8]

In particular, when it comes to muscle measurement in HD patients, we must pay attention that a tremendous change in fluid hydration status of muscle occurs before

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and after the HD procedure. This kind of change may have a great influence on muscle measurements.[9,10] As far as we know, no data are currently available on whether rapid fluid shifts occurring during the HD procedure might influence US measurements of muscle mass and EI.

Therefore, we try to explore the effects of fluid hydration status on ultrasound muscle measurement in HD patients by measuring CSA, MT, and EI of the rectus femoris by ultrasound and comparing these values before and after the HD procedure.

Methods

Patient Selection

This study included patients who had undergone more than 3 months of HD, and those who could not walk or be completely blind were excluded. A total of 50 subjects were eventually analyzed. This study was approved by the ethics committee of the hospital. All subjects signed the written informed consent.

Study Protocol

Baseline characteristics, including age, sex, weight, height, disease history, and duration of HD were collected for all participants before HD. The whole-body bioelectrical impedance analysis (BIA) measurement of the right lower limb and ultrasound examination of the rectus femoris were performed before and after HD. Body mass index was calculated as dry weight (kg)/height^2 (m^2). Ultrafiltration volume was collected and the dialysis dose was evaluated by calculating Kt/V.[11]

Bioelectrical Impedance Analysis Measurement

The patient was positioned supine. Water parameters of the right lower limb, including total body water (TBW), intracellular water (ICW), and extracellular water (ECW), were obtained before and after the HD procedure by a multifrequency BIA (InBody S10; InBody Co., Ltd., Seoul, South Korea). The values of phase angles were also recorded by the device at a frequency of 50 kHz. The differences between the values before and after HD were calculated.

Ultrasound Measurement

A 50-mm width linear transducer (5-14 MHz, S II; SonoSite Inc., Bothell, Washington) was used to measure the right rectus femoris muscle before and after HD. All ultrasound images were standardized by the default machine settings (depth, gain, and focus).

The patient was positioned in the supine position at a 45° angle. The ultrasound transducer was placed at the midpoint between the anterior superior iliac spine and the superior patellar border of the right leg. Two 2-dimensional images of the rectus femoris images were obtained at each time. Ultrasound images were transferred to the computer for measurements using ImageJ software (National Institute of Health). The whole rectus femoris muscle within its epimysium was circled as the region of interest, and the software returned measures of CSA, MT, and mean EI values.[12] The average values of the 2 images at the same time were obtained for statistical analysis.

Statistical Analysis

Continuous data are presented as mean ± standard deviation, and categorical data are presented as a percentage. Changes and percentage changes in CSA, MT, and EI obtained before and after the HD procedure are compared by a paired Wilcoxon test or signed rank-sum test. Spearman correlation coefficients were performed to determine the correlation between the change in CSA, MT, or EI from predialysis to postdialysis and changes in TBW, ICW, or ECW of the right lower limb. All statistical analyses were performed by SPSS software (Version 22.0; IBM). $P < .05$ was considered statistically significant.

Results

Patient characteristics, Kt/V, and ultrafiltration volume are presented in Table 1.

The values of ultrasound CSA, EI, and MT of the rectus femoris before (predialysis) and after HD (postdialysis) are presented in Table 1. The CSA, MT, and EI and their percentage changes all decreased significantly after the HD procedure for the entire group (Table 2). When grouped by gender, the CSA and EI and their percentage changes decreased significantly in the female group; the CSA and EI and their percentage changes decreased significantly in the male group (Table 2). The percentage change in CSA was more significant (−6.6%) than in MT (−2.8%). Representative ultrasound images of one patient's rectus femoris obtained before and after the HD session are

Table 1. Main Demographic and Clinical Characteristics of Patients on Hemodialysis (n = 50)

Item	All (n = 50)
Age (y)	52.6 ± 13.5
Female sex, n (%)	20 (40)
BMI (kg/m^2)	21.48 ± 3.45
Ethnicity, n (%)	
Han	12 (24)
Dai	24 (48)
Hani	7 (14)
Other	7 (14)
Hypertension, n (%)	47 (94)
Diabetes, n (%)	5 (10)
Primary disease, n (%)	
Chronic glomerulonephritis	9 (18)
Diabetic nephropathy	4 (8)
Hypertensive nephropathy	8 (16)
Obstructive nephropathy	7 (14)
Other or unknown	22 (44)
Dialysis duration (y)	1.73 (1.29-4.24)
Kt/V	1.28 ± 0.10
Ultrafiltration volume (L)	2.71 ± 1.49

BMI, body mass index.

Table 2. Changes in Cross-Sectional Area, Muscle Thickness, Muscle Echo Intensity and Phase Angle Before and After Dialysis in HD Patients (n = 50)

Number of Patients	All (n = 50)	Male (n = 30)	Female (n = 20)
Predialysis CSA (cm^2)	6.10 ± 1.45	6.81 ± 1.32	5.05 ± 0.93
Postdialysis CSA (cm^2)	5.70 ± 1.44	6.39 ± 1.36	4.66 ± 0.81
Change in CSA (cm^2)	−0.41 ± 0.58*	−0.42 ± 0.69*	−0.39 ± 0.38*
Percentage change in CSA (%)	−6.6 ± 7.8*	−6.0 ± 8.6*	−7.5 ± 6.5*
Predialysis MT (cm)	1.60 ± 0.28	1.72 ± 0.29	1.42 ± 0.14
Postdialysis MT (cm)	1.55 ± 0.26	1.67 ± 0.23	1.36 ± 0.18
Change in MT (cm)	−0.06 ± 0.17†	−0.05 ± 0.20	−0.06 ± 0.12†
Percentage change in MT (%)	−2.8 ± 10.8†	−1.7 ± 12.1	−4.5 ± 8.6†
Predialysis EI	47.39 ± 12.48	42.94 ± 11.84	54.06 ± 10.46
Postdialysis EI	45.00 ± 11.89	39.44 ± 9.32	53.35 ± 10.48
Change in EI	−2.39 ± 5.78‡	−3.51 ± 6.56‡	−0.71 ± 3.93
Percentage change in EI (%)	−4.2 ± 11.5†	−6.2 ± 13.2†	−1.2 ± 7.7
Predialysis PhA	4.77 ± 1.13	4.83 ± 1.15	4.67 ± 1.11
Postdialysis PhA	5.83 ± 1.45	5.92 ± 1.56	5.70 ± 1.29
Change in PhA	1.07 ± 0.58*	1.09 ± 0.66*	1.03 ± 0.42*
Percentage change in PhA (%)	22.4 ± 11.8*	22.6 ± 12.9*	23.0 ± 10.2*

CSA, cross-sectional area; EI, echo intensity; HD, hemodialysis; MT, muscle thickness; PhA, phase angle.
*$P < .001$.
†$P < .05$.
‡$P < .01$.

illustrated in Figure 1. Compared to predialysis, the rectus femoris muscle looked smaller in CSA, thinner in MT, and darker in EI after the HD procedure.

The TBW, ICW, and ECW of the right leg decreased 0.53 ± 0.28 L, 0.25 ± 0.16 L, and 0.28 ± 0.13 L, respectively. The values of ECW/TBW ratio of the lower limb before and after the HD procedure were 0.40 ± 0.01 and 0.38 ± 0.02 respectively ($P < .001$). The phase angle and its percentage changes decreased significantly after the HD procedure, whether or not grouped by gender (Table 2). As shown in Table 3, EI, with its percentage change, is the only value to correlate significantly with changes in TBW, ICW, ECW, Kt/V, and ultrafiltration volume (all $P < .05$) among the ultrasound values and their changes.

Discussion

In the present study, we found that both ultrasound CSA and MT—the 2 indicators of muscle quantity of rectus femoris—decreased after the HD procedure.

At different periods of predialysis and postdialysis, the fluid hydration status will change and may affect the muscle measurements. Barreira et al.[13] indicated that acute water ingestion before a DXA analysis would significantly influence body composition. However, Sabatino et al.[5] compared quadriceps MT values measured by ultrasound

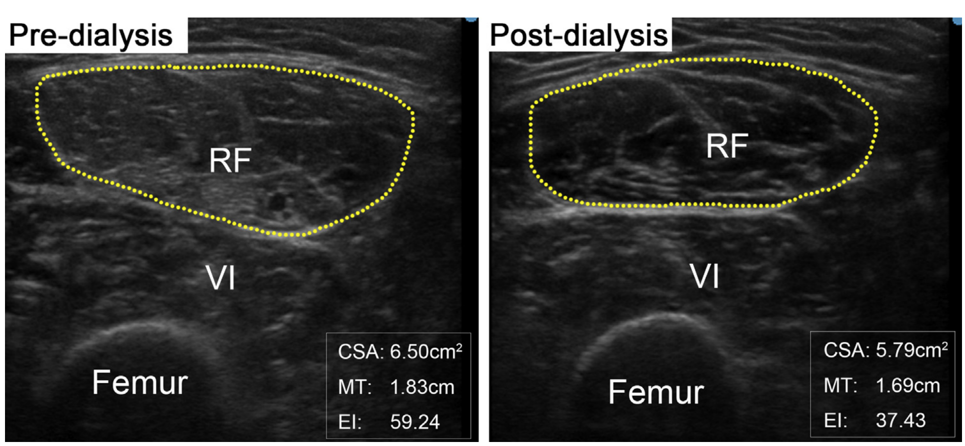

Figure 1. Representative comparison ultrasound images of predialysis and postdialysis obtained from the same rectus femoris location of one of the patients. The patient was 36 years old, male, and with a 7-year dialysis duration. Rectus femoris cross-sectional area is outlined by dotted line. The CSA, MT, and EI values of each image are marked at the lower right corner of the image. CSA, cross-sectional area; EI, echo intensity; MT, muscle thickness; RF, rectus femoris; VI, vastus intermedius.

Table 3. Correlation of Changes in Cross-Sectional Area, Muscle Thickness, and Muscle Echo Intensity With Changes in Total Body Water, Intracellular Water, and Extracellular Water in HD Patients (n = 50)

Items	Change in CSA	Change in MT	Change in EI	Percentage Change in CSA (%)	Percentage Change in MT (%)	Percentage Change in EI (%)
Age	rho = −0.106 *P* = .464	rho = 0.022 *P* = .879	rho = 0.175 *P* = .224	rho = −0.125 *P* = .388	rho = −0.101 *P* = .946	rho = 0.127 *P* = .378
BMI	rho = −0.106 *P* = .916	rho = 0.041 *P* = .778	rho = −0.022 *P* = .880	rho = −0.063 *P* = .664	rho = 0.130 *P* = .931	rho = −0.106 *P* = .916
Kt/V	rho = 0.213 *P* = .138	rho = 0.085 *P* = .555	rho = 0.346 *P* = .014	rho = 0.193 *P* = .179	rho = 0.043 *P* = .768	rho = 0.370 *P* = .008
Ultrafiltration volume	rho = 0.225 *P* = .116	rho = 0.139 *P* = .336	rho = 0.337 *P* = .017	rho = 0.181 *P* = .209	rho = 0.085 *P* = .558	rho = 0.364 *P* = .009
Change in TBW	rho = 0.033 *P* = .818	rho = 0.047 *P* = .746	rho = 0.333 *P* = .018	rho = −0.024 *P* = .869	rho = 0.001 *P* = .992	rho = 0.386 *P* = .006
Change in ICW	rho = 0.058 *P* = .687	rho = 0.003 *P* = .981	rho = 0.331 *P* = .019	rho = 0.008 *P* = .954	rho = 0.010 *P* = .945	rho = 0.370 *P* = .008
Change in ECW	rho = 0.007 *P* = .960	rho = −0.010 *P* = .946	rho = 0.314 *P* = .026	rho = −0.051 *P* = .726	rho = −0.075 *P* = .606	rho = 0.378 *P* = .007

BMI, body mass index; CSA, cross-sectional area; ECW, extracellular water; EI, echo intensity; HD, hemodialysis; ICW, intracellular water; MT, muscle thickness; TBW, total body water.

before and after renal replacement therapy and found no significant differences. This result was somewhat contrary to ours, and the explanation may be that they use MT, a 1-dimensional single-axis data, as the only indicator of muscle mass, which may not represent the total 3-dimensional volume of muscle. In our study, both the CSA value, a 2-dimensional area data, and the MT value were recorded. Our results showed that the CSA value changed more significantly than the MT value, which changed very little. Besides, we compared the changes in CSA and MT with changes in TBW, ICW, and ECW of the lower limb measured by BIA. The difference in ECW/TBW ratio before and after the HD procedure was very weak, so we did not compare them with ultrasound measures. It turned out that neither the changes in CSA nor MT were correlated significantly with the water parameters. To a certain extent, this result went beyond what we expected. We considered this result for some possible explanations. First, the local rectus femoris muscle actually does not represent the total body muscle or the lower limber. Second, the muscle architecture change is more complicated than BIA change, and will not change proportionally with a water change. Third, after the HD procedure, not only did the area of the rectus femoris decrease but also the rigidity of the rectus femoris muscle improved. Then the muscle's morphology transformed subtly, which may make the changes in CSA and MT more complicated than the primary change with the hydration status shifting before and after the HD procedure. Eventually, the actual changes in CSA and MT we obtained by ultrasound were not significant enough to correlate with the changes in water parameters. Nevertheless, the evidence of a decrease in CSA and MT provided by the present study is not strong, so further cross-sectional studies with a larger sample are needed to clarify how the change in fluid hydration status affects ultrasound measurement of muscle quantity.

Importantly, we also found that ultrasound EI of rectus femoris, the indicator of muscle quantity, decreased after the HD procedure significantly in the current study. An increase in skeleton muscle EI generally indicates various structural changes in the muscle, such as fatty infiltration, fibrosis, or edema.[14,15] Increased muscle ultrasound EI correlated strongly with decreased muscle strength and has been confirmed in different neuromuscular disorders.[16] Our study results showed that, as the fluid was cleared and the edema status was improved in the muscle tissue in the cases of HD patients, the ultrasound EI of skeleton muscle decreased. Furthermore, compared to changes in TBW, ICW, and ECW of the lower limb measured by BIA, the change in EI, but not CSA and MT, was correlated significantly with all these water values. Similarly, compared to the values of Kt/V and ultrafiltration volume, the change in EI was the only ultrasound parameter to correlate significantly with all these BIA water values. This finding suggested that the change in EI correlated more strongly with the change in the hydration status of the muscle than those muscle quantity indicators of CSA and MT. We attributed this difference to the following reasons. First, EI is determined by quantifying the intensity of a pixel within an ultrasound image of the transverse plane of the rectus femoris, and it might be less affected by changes in the overall muscle shape. Second, beyond the change in hydration status, the HD session will produce the change in fluid composition, the changes in ultrasound muscle EI, CSA, and MT might be more complicated than the change in BIA. Damas et al.[17] found that both muscle CSA and EI increased in early resistance training adults, but the degree was not always consistent.

There were several limitations in the present study. First, the sample size is limited, hampering further evaluation regarding differences in the results grouped by gender. Second, we assessed the fluid status by BIA instead of DXA. We did not use computed tomography or magnetic resonance imaging to further confirm the CSA results and the femoris rectus measured by ultrasound might not reflect whole-body muscle quantity and quality. Third, we just tried to illustrate the effects of acute dehydration on muscle measurements. But what we should keep in mind is the effect of the HD session is more than the change in fluid status. As we assumed, the fluid was redistributed in dehydrated muscles in a short time after the HD procedure. Finally, ultrasound EI may be easily influenced by the degree of ultrasound probe tilt with the muscle, and there is still no standardized technique for EI measurement yet. Further studies are urgently needed to make EI measurement standardized to get reproducible evidence.

Conclusion

This study has revealed that the HD session may significantly have effects on ultrasound muscle measurement. Both the indicators of muscle quantity (CSA and MT) and quality (EI) significantly decreased after the HD procedure, but the changes in muscle quantity were not correlated with the changes in TBW, ICW, and ECW of the lower limb. The changes in muscle measurements may contribute to both the change in fluid hydration status and the change in fluid composition.

Practical Application

Ultrasound skeleton muscle measurement is convenient, nonradiative, and it may help us in identifying muscle changes in nutritional disturbances like sarcopenia, protein energy wasting, and frailty. When we evaluate the muscle mass and quality in HD patients, we recommend to assess muscle mass by ultrasound after the session of dialysis.

Credit Authorship Contribution Statement

Dongsheng Cheng: Data curation, Formal analysis, Investigation, Methodology, Visualization, Writing – original draft. **Haiqing Luo:** Data curation, Formal analysis, Investigation. **Shunrong Ren:** Investigation, Validation, Visualization. **Niansong Wang:** Conceptualization, Funding acquisition, Methodology, Project administration, Resources, Supervision, Writing – review & editing. **Junzhen Wu:** Conceptualization, Project administration, Resources, Supervision, Writing – original draft, Writing – review & editing.

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